SPECIAL CONTRIBUTIONS.

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THE ROENTGEN RAYS.

By Prof. JOHN TROWBRIDGE (from the Harvard Graduates Magazine for June, 1897).

The investigations in the Jefferson Physical Laboratory of Harvard University on the subject of the Roentgen rays have been directed to the more purely scientific side of the question of discharge of electricity through gases, a subject of which the Roentgen rays is only a part. The most familiar example of the discharge of electricity through gases is a stroke of lightning. This discharge develops, so to speak, a current of electricity which is similar to that by means of which we telegraph or telephone, but its duration is extremely short. In its passage it encounters a resistance *in the air* instead of *on a telegraph wire*. Moreover, it passes to and fro or oscillates, and the time it takes to make an excursion in one direction is barely a millionth of a second, while the to and fro motions on a telephone wire are nearly a thousand times slower. When the lightning discharges take place in the higher regions of the air, where the air is highly rarefied, we have instead of the zigzag white flash of lightning the red and yellow auroral streamers. All of these manifestations of the discharges of electricity can be imitated in a laboratory, and by exhausting glass tubes of almost every trace of air we at length obtain a discharge of electricity which produces the Roentgen rays.

There is no break in the continuity of the phenomena of electricity from the current by means of which we telegraph and telephone, through the various manifestations of lightning and the northern lights, up to the production of the Roentgen rays; and it may be that the corona of the sun, with its strange streamers which are only visible during an eclipse of the sun, is a manifestation of the discharge of electricity, and that the earth is one pole of a species of electrical machine and the sun the other pole, and that in our whirling through space we pass through great streamers of the corona and are conscious of electrical disturbances in the form of northern lights; and it may be that the physical and mental conditions of humanity are influenced in ways unsuspected by the changes in our electrical condition.

When we thus consider the phenomena of the discharge of electricity through gases, we see that the manifestation of the Roentgen rays, in revealing the skeleton of the human body, is only a comparatively small phenomenon in a great subject which involves the life of the human race; for light and heat are now considered as electrical phenomena, and it is impossible to find a space on this earth which is free from electromagnetic waves, unless, indeed, we place ourselves in a hermetically sealed lead or iron chamber from which all air has been exhausted. Thus it may be said that life and electricity die together.

In order to study the energy manifested by the Roentgen rays, I have had constructed a storage battery of ten thousand cells, which I believe is the largest storage battery at present in existence. The object of such a battery is to obtain a steady source of electricity. Each cell of this battery develops a certain amount of electricity, which can be closely estimated. When the battery is exhausted it is readily recharged by a dynamo, and one can by its means exhibit all the phenomena of electricity from the Edison filament lamp, the arc light, the phenomena of magnetism, and the discharges of electricity through gases. A discharge of electricity in the shape of a flame three feet high can be obtained by connecting the ends of the battery and suddenly separating them, and it is highly dangerous to touch the terminals of the battery, since the voltage or electrical pressure amounts to 20,000 volts. This pressure can be exalted almost to any extent. I have used from 300,000 to 500,000 volts.

With this battery I have ascertained that it requires about 100,000 volts to produce the Roentgen rays, and the energy required amounts to about 3,000,000 horse power acting for one-millionth of a second. The duration of this exhibition of energy is exceedingly short and, therefore, the work if spread over a second would seem very small. Nevertheless, we perceive that the shock given to the molecules of matter must be extremely powerful; and we can understand why the Roentgen rays can pass through blocks of wood more than a foot thick, can penetrate human flesh, and can blacken photographic plates in dark rooms at least sixty feet away from the little Crooke's tubes in which the rays are generated.

The most interesting fact, however, which I have discovered is this: When the Roentgen rays are being developed with the greatest intensity, the discharge of electricity encounters very little resistance in passing through the attenuated space inside the Crooke's tubes. It has been believed hitherto that a vacuum can not conduct electricity. My experiments, however, lead me to conclude that under certain conditions it can be made to conduct, and that it offers hardly any resistance to a disruptive discharge of electricity. When the discharge is started it appears to go with the greatest ease. This fact leads to interesting suppositions in regard to the structure of the ether of space. The discovery of the Roentgen rays has given a great impulse to the subject of the discharge of electricity through gases, and the Jefferson Physical Laboratory has now important means and methods of studying the great problem of the mechanism of this discharge of electricity in rarefied media.

ON THE MECHANICS OF THE KITE.[1]

By Horace M. Decker, B. S., Irvington, Essex Co., N. J. (dated December, 1896).

The kite as a motor for ascension depends on the dynamic effects of the impulse of wind on plane surfaces.

The pressure of wind on a plane surface at right angles to the direction of motion is given by the well-known equation

$$P = k\,a\,w\,h, \tag{1}$$

which measures the inertia of the column of fluid encountered. a is the area of the plane in square feet; w is the weight of a cubic foot of air which may be taken in ordinary as 0.08 pound avoirdupois; $h = v^2 \div 2g$ is the "head" of the current. The coefficient k has been determined by different experimenters to be about 1.70 for average wind velocities. The average of the writer's experiments is 1.72. Of course the value of the factor w will vary somewhat with the ordinary thermic and barometric changes and the value of k should increase with the velocity. However, the above approximations are good in ordinary conditions.

When the plane is inclined to the direction of the current like a kite, the previous relations are curiously changed. Both the pressure normal to the plane and its center of application, which was the center of area, vary with the contour or form and the degree of inclination.

[1] In accordance with the policy of publishing the views of those who have written on the theory of the kite, the Editor is permitted to reproduce, herewith, the essay of Mr. Horace M. Decker, whose graduating thesis with experiments on the resistance of the air formed an early contribution to meteorology in its relation to engineering.

To Duchemin is due the following equation for wind pressure on inclined planes:

$$P_n = P_{90} \frac{2 \sin a}{1 + \sin^2 a}$$

P_n is the resultant pressure normal to the plane, while P_{90} is the pressure on the plane, when at right angles to the current, as given by equation (1); a is the inclination of wind to the surface of the plane.

Duchemin's determination gives results closely confirmed for a square plane by experiments made in London by Wenham for the English Aeronautical Society and by those of S. P. Langley. The first and last results are presented by the curves of Fig. 1, Chart VI. The influence of the form of the plane is shown by the curves of relative pressures in Fig. 2, as determined by Langley, for plates of the same area but different proportions.

In making kites the square or approximations thereto are more common and with these forms the pressure will follow closely enough the law of Duchemin. A curve of the values of Duchemin's factor for the normal pressure is given in Fig. 3, as also curves for the ratio of the horizontal and vertical components $P_{,}$ and $P_{,,}$ respectively. Fig. 4 shows the position of center of pressure d/l with varying degrees of inclination for a square plane as determined by different experimenters, where d is the distance between the center of area and center of pressure for varying angles of inclination and l is the length of the side of the square plane. Where the form is other than rectangular, special figuring by areas must determine the approximate values of d.

In the kite we find a static couple about the center of pressure and stable equilibrium because the center of gravity of the plane is carried below the center of pressure either by the form or by the addition of ballast.

In Fig. 5, let P_n be the normal pressure, $P_{,}$, $P_{,,}$ are its components, s is the string, $S_{,}$, $S_{,,}$ are the components of its tension, W represents the total weight of the plane and its ballast acting from the center of gravity (w). Supposing the interbalance of forces to be complete and the plane in stable, uniform flight, then

$$Wd = S_{,,}\, d, \tag{2}$$

$$S_{,} = P_{,} \tag{3}$$

$$W + S_{,,} = P_{,,} \tag{4}$$

and approximately the line tension

$$S = \sqrt{P_{,}^2 + (P_{,,} - W)^2} \tag{5}$$

The center of gravity of the plane is usually near its center of area. With ballast the center of gravity will be lowered by the distance x,

$$x = l \frac{W_{,,}}{W_{,} + W_{,,}} \tag{6}$$

Where $W_{,}$ is weight of plane and $W_{,,}$, the weight of ballast, l, being the distance between the centers of gravity. But as the tail will be blown back at an angle t with the vertical and partly supported by wind pressure, therefore

$$W_{,,} = W_t - P_t \sin t.$$

where P_t is the pressure normal to the tail. The relation

$$\sqrt{W_t^2 + (W_t \sin t)^2} > P_t$$

must exist if the tail is to have much effect on the plane at ballast. If the wind pressure does overcome the weight of the tail, the kite will begin to fall spinning, and then ballass presenting less cross section must be chosen.

It is evident that the line tension S is measured by the deflections due to wind pressure and the weight of the cord. The value of the components of these forces may be determined (by an impracticable equation), but it is enough to say that with a continued paying out of line, the kite will